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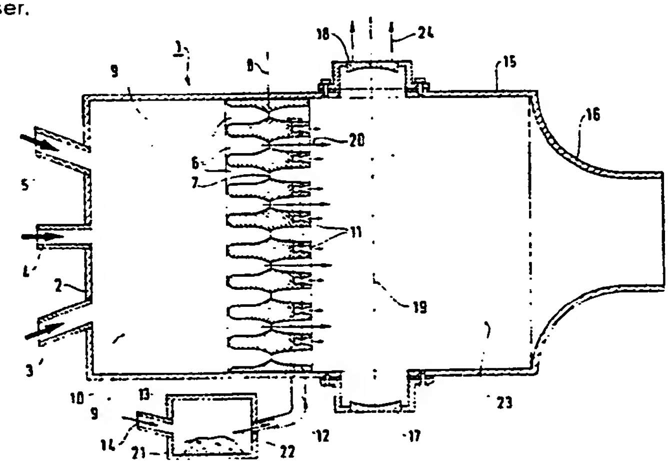
(54) A method of chemically generating a 1.315 micron CW laser beam

(57) A first gas containing atomic fluorine is formed and then expanded through supersonic nozzles (6). A second gas containing molecular iodine (21) is injected into the first as it leaves the nozzles. As these two gases react to form a third gas containing excited iodine atoms they are passed through a resonant optical cavity (17-18), thus providing a continuous wave chemical iodine laser.



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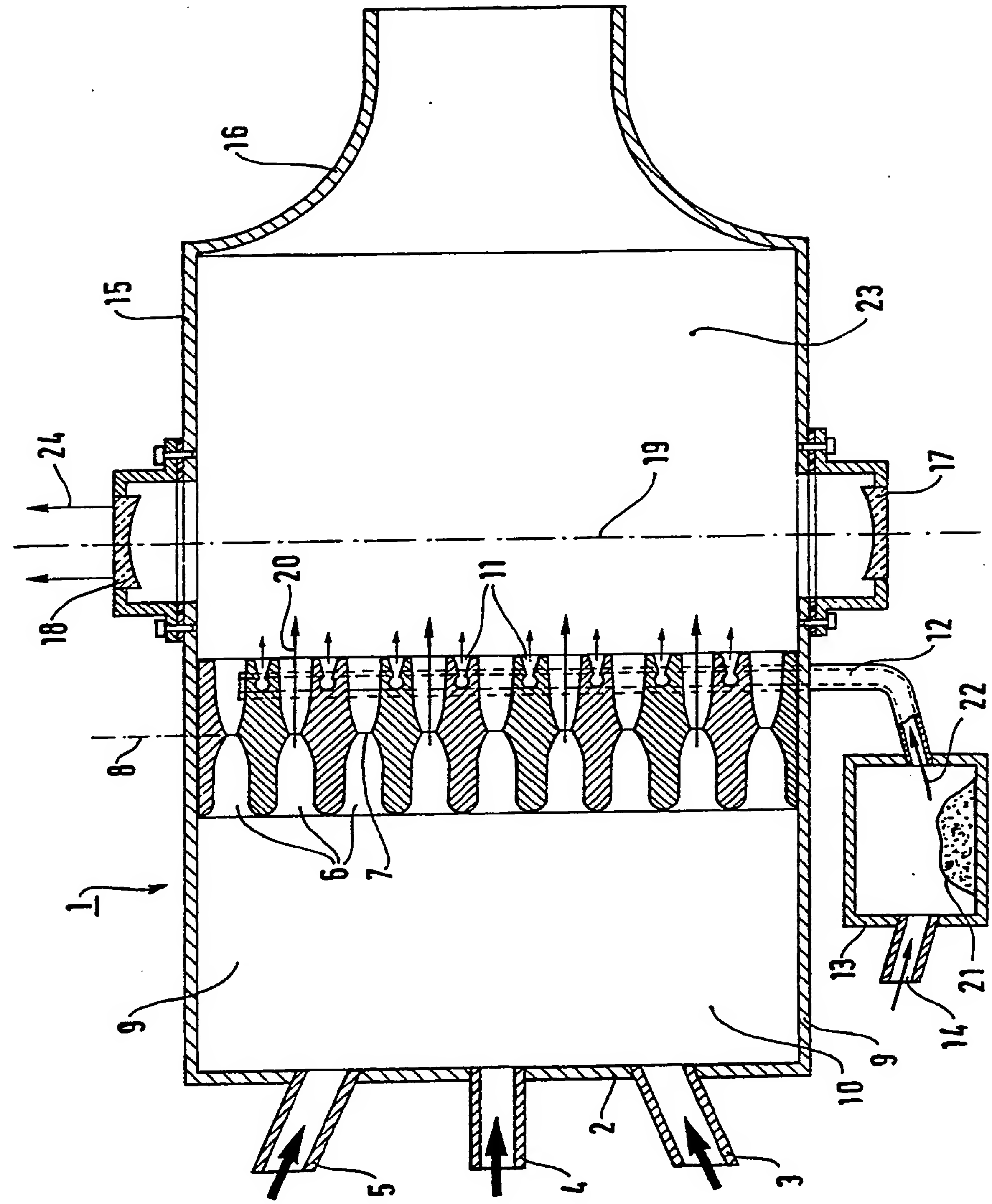
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A METHOD OF CHEMICALLY GENERATING A 1.315 MICRON CW LASER BEAM

This invention relates to a method of chemically generating a 1.315 micron wavelength continuous wave (CW) laser beam.

It is known to chemically generate laser beams by forming a first gas;

introducing a second gas into said first gas, said second gas including molecular iodine, and the first gas reacting with the molecular iodine to cause a third gas to be formed containing excited iodine atoms; and

passing said third gas through a resonant optical cavity in order to obtain said laser beam.

A method of this type is described in US patent No.4,267,526. In this particular method, the first gas is constituted by excited molecular oxygen in the 1Δ electron state. The excited oxygen is produced by reacting chlorine gas with oxygenated water. Although CW laser generators can be made which operate on the basis of the excitation energy of the oxygen being transferred to the iodine, this known method suffers from several drawbacks, including:

1) the reaction which produces the excited oxygen also produces water which it is important to eliminate, e.g. by means of a cryogenic trap which considerably complicates the installation;

2) the gas pressure during operation is very low, e.g. 2 to 3 torrs. Thus a power laser of this type operating in an ambient medium at atmospheric pressure requires substantial pumping means particularly since the laser gas flows at subsonic speeds and therefore cannot be recompressed in a diffuser; and

3) the laser amplification coefficient is low, e.g. about 0.1% per centimeter (cm).

Preferred embodiments of the present invention

mitigate the above drawbacks.

According to one aspect of the present invention there is provided a method of chemically generating a 1.315 micron wavelength continuous wave laser beam, said method comprising the following successive steps:

(a) forming a first gas including atomic fluorine;

(b) expanding said first gas through supersonic nozzles;

(c) introducing a second gas into said first gas at the outlets from said nozzles, said second gas including molecular iodine and the first gas reacting with the molecular iodine to cause a third gas to be formed containing excited iodine atoms; and

(d) passing said third gas through a resonant optical cavity in order to obtain said laser beam.

According to another aspect of the present invention there is provided an apparatus for chemically generating a 1.315 micron wavelength continous wave laser beam, which apparatus comprises:

(a) a first chamber to contain a first gas including atomic fluorine,

(b) an expansion chamber having a wall in common with the first chamber,

(c) a plurality of nozzles in said wall whereby said first gas can pass from the first chamber into the expansion chamber at supersonic speed,

(d) a means of introducing, into the expansion chamber in the vicinity of the nozzles, a second gas comprising molecular iodine for reaction with the first gas to form a third gas containing excited iodine atoms, and

(e) a resonant optical cavity in the expansion chamber for forming said beam as the third gas passes through it.

For a better understanding of the invention and to

show how the same may be carried out, reference will now be made, by way of example, to the accompanying drawing which shows a longitudinal section through a chemical laser for carrying out the method of the present invention.

Referring to the figure, there is shown a rectangular vessel 1 having three gas injectors 3,4 and 5 mounted in a wall 2 thereof. The wall of the vessel which is opposite wall 2 is constituted by juxtaposed supersonic nozzles 6 having parallel axes. Each nozzle 6 has a throat 7 disposed in a plane which lies half way through the thickness of the wall. The throats 7 are preferably of rectangular section and elongated in a plane perpendicular to the plane of the figure, with the throat rectangles having their long sides adjacent one another.

The nozzles 6, wall 2, and vessel side walls 9 delimit a combustion chamber 10. On that side adjacent to the combustion chamber, each nozzle 6 has an inlet of rectangular cross section tapering down to its throat 7. Each nozzle 6 has a flared outlet on that side most remote from the combustion chamber. Flared orifices 11 are provided between adjacent nozzles in the thickness of the nozzle walls and open out away from the combustion chamber 10. These orifices 11 are connected by ducting to a gas inlet duct 12 leading to a container 13 which includes a gas inlet opening 14.

The vessel side walls 9 include portions 15 which extend beyond the nozzles 6 to form an expansion chamber 23 which terminates in a diffuser 16. Two facing mirrors 17 and 18 are mounted in the portions 15 to constitute a resonant optical cavity having an axis 19 which is perpendicular to the axes of the nozzles 6. The mirror 17 is totally reflective, while the mirror 18 is partially transparent.

The laser shown in the figure operates as follows:

Gases including deuterium, a fluorine-containing combustive substance such as molecular fluorine or nitrogen trifluoride, and an inert gas such as argon or helium, are injected into the combustion chamber 10 via the injectors 3,4 and 5. If the combustive substance is fluorine, combustion with the deuterium takes place spontaneously. If the combustive substance is nitrogen trifluoride, combustion must be triggered by means of an electric device (not shown) analogous to the spark plug for an internal combustion engine. In any event, the combustion causes the fluorine-containing combustive substance to dissociate and provide in said combustion chamber a gas which is a mixture containing atomic fluorine and deuterium fluoride acid (DF) diluted with the inert gas at a pressure of a few bars and at a temperature greater than 1500°K. This mixture enters the expansion chamber 3 via the nozzles 6 at supersonic speed in the direction of arrow 20 where it expands and cools.

Simultaneously, an inert gas such as argon is injected via the inlet opening 14 into the container 13 which contains previously inserted iodine crystals 21. There is thus formed a gas comprising argon impregnated with molecular iodine vapor and this flows along the duct 12 in the direction of arrow 22 so as to be injected via orifices 11 into the expansion chamber 23 in parallel with and adjacent to the gas entering the expansion chamber 23 via the nozzles 6. In order to obtain sufficient iodine vapor pressure and to avoid iodine condensing on the cold walls of the chamber 23, the container 13 may be fitted with heating means (not shown) suitable for raising its temperature to about 50°C or more.

In the expansion chamber the atomic fluorine reacts with the molecular iodine to form a gas containing

excited atomic iodine in the $^{2}P_{1/2}$ state in accordance with the exothermic reaction:

$$F + I_2 \text{ --> } IF + I^*$$

The gas mixture containing the excited iodine passes through the optical cavity 17-18, thereby causing a continuous wave chemical iodine laser beam 24 to be generated at a wavelength of 1.315 microns.

It is important to use deuterium for reaction with the fluorine-containing combustive substance to form the fluorine atoms. If hydrogen is used instead, the combustion reaction produces hydrofluoric acid HF. Unfortunately, the vibration frequency of HF molecules in the expansion chamber is suitable for exchanging energy with excited atomic iodine and this would result in a considerable reduction in laser amplification at a wavelength of 1.315 microns. This energy exchange pehenomenon does not occur with the DF molecules which are formed by the combustion of deuterium with the fluorine-containing combustive substance.

Instead of producing atomic fluorine by combustion of deuterium and a fluorine-containing combustive substance, it can be produced by dissociating a fluorine compound such as F_2, NF_3 or SF_6 using an electric discharge.

The following Example illustrtes the invention.

A gas mixture composed of 10% atomic fluorine, 10% DF acid and 80% argon (% by volume) was provided in the combustion chamber of an apparatus as shown in the drawing. The mixture was expanded by passing it through the nozzles to reach a temperature of 250°K . The gas flowed through the nozzles at Mach 2.5, and reacted, in the expansion chamber with a gas containing molecular iodine to form excited atomic iodine. The gas pressure in the expansion chamber, was 5 to 10 torrs and the gas flowed therethrough at 700 metres/sec. Under such

conditions, the laser amplification coefficient at 1.315 microns was about 1% to 2% per cm and extended over a length of more than 5 cm.

The above amplification coefficients are an order of magnitude greater than those obtained with lasers as described in the above-mentioned US patent.

The method in accordance with the invention has the advantage of producing excited iodine atoms directly without producing water.

The method in accordance with the invention also has the advantage of enabling the exhaust gas to be removed directly at atmospheric pressure by means of a diffuser and a gas ejector.

The method in accordance with the invention enables iodine lasers to be obtained having a specific power which is comparable to that of HF/DF chemical combustion lasers.

CLAIMS

1. A method of chemically generating a 1.315 micron wavelength continuous wave laser beam, said method comprising the following successive steps:

(a) forming a first gas including atomic fluorine;

(b) expanding said first gas through supersonic nozzles;

(c) introducing a second gas into said first gas at the outlets from said nozzles, said second gas including molecular iodine and the first gas reacting with the molecular iodine to cause a third gas to be formed containing excited iodine atoms; and

(d) passing said third gas through a resonant optical cavity in order to obtain said laser beam.

2. A method according to claim 1, wherein said first gas including atomic fluorine is formed by the combustion of deuterium with a fluorine-containing combustive substance.

3. A method according to claim 2, wherein the fluorine-containing combustive substance is molecular fluorine.

4. A method according to claim 2, wherein the fluorine containing combustive substance is nitrogen trifluoride.

5. A method according to claim 2, 3 or 4 wherein the combustion of the deuterium with the fluorine-containing combustive substance takes place in the presence of an inert gas.

6. A method according to claim 5 wherein the inert gas is argon or helium.

7. A method according to claim 1 wherein said first gas including atomic fluorine is formed by dissociating a fluorine containing compound using an electrical discharge.

8. A method according to claim 7 wherein said

fluorine containing compound is molecular fluorine, nitrogen trifluoride or sluphur hexafluoride.

9. A method according to any one of the preceding claims wherein said second gas includes an inert gas.

10. A method according to claim 9 wherein the inert gas is argon.

11. A method according to claim 1 substantially as hereinbefore described with reference to the accompanying drawing.

12. An apparatus for chemically generating a 1.315 micron wavelength continous wave laser beam, which apparatus ocmprises:

(a) a first chamber to contain a first gas including atomic fluorine,

(b) an expansion chamber having a wall in common with the first chamber,

(c) a plurality of nozzles in said wall whereby said first gas can pass from the first chamber into the expansion chamber at supersonic speed,

(d) a means of introducing, into the expansion chamber in the vicinity of the nozzles, a second gas comprising molecular iodine for reaction with the first gas to form a third gas containing excited iodine atoms, and

(e) a resonant optical cavity in the expansion chamber for forming said beam as the third gas passes through it.

13. An apparatus as claimed in claim 12 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawing.

Amendments to the claims have been filed as follows

1. A method of chemically generating a 1.315 micron wavelength continuous wave laser beam, said method comprising the following successive steps:

(a) forming a first gas including atomic fluorine;

(b) expanding said first gas through supersonic nozzles;

(c) introducing a second gas into said first gas at the outlets from said nozzles, said second gas including molecular iodine and the first gas reacting with the molecular iodine to cause a third gas to be formed containing excited iodine atoms; and

(d) passing said third gas through a resonant optical cavity in order to obtain said laser beam.

2. A method according to claim 1, wherein said first gas including atomic fluorine is formed by the combustion of deuterium with a fluorine-containing combustive substance.

3. A method according to claim 2, wherein the fluorine-containing combustive substance is molecular fluorine.

4. A method according to claim 2, wherein the fluorine containing combustive substance is nitrogen trifluoride.

5. A method according to claim 2, 3 or 4 wherein the combustion of the deuterium with the fluorine-containing combustive substance takes place in the presence of an inert gas.

6. A method according to claim 5 wherein the inert gas is argon or helium.

7. A method according to claim 1 wherein said first gas including atomic fluorine is formed by dissociating a fluorine containing compound using an electrical discharge.

8. A method according to claim 7 wherein said

fluorine containing compound is molecular fluorine, nitrogen trifluoride or sulphur hexafluoride.

9. A method according to any one of the preceding claims wherein said second gas includes an inert gas.

10. A method according to claim 9 wherein the inert gas is argon.

11. A method according to claim 1 substantially as hereinbefore described with reference to the accompanying drawing.

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